INDOOR AIR QUALITY ASSESSMENT

Kitteridge Elementary School
601 Main Street
North Andover, Massachusetts

Prepared by:
Massachusetts Department of Public Health
Bureau of Environmental Health Assessment
June, 2002

Background/Introduction

At the request of Paul Szymanski, Director of Management Support Services for the North Andover Public Schools, the Massachusetts Department of Public Health (MDPH), Bureau of Environmental Health Assessment (BEHA) provided assistance and consultation regarding indoor air quality concerns at Kitteridge Elementary School in North Andover, Massachusetts. On January 22, 2002, a visit was made to this building by Michael Feeney, Director of Emergency Response/Indoor Air Quality (ER/IAQ), BEHA to conduct an indoor air quality assessment. Mr. Feeney was accompanied by Suzan Donahue, ER/IAQ Research Analyst. Douglas Speight, custodian, Kitteridge School, accompanied BEHA staff during the assessment.

Kitteridge School is a multi-story, red brick building constructed in 1950. The school is built along a slope, on ground formed by the fork of Main Street and Chickering Road (Rte. 133) (see Map 1). The schoolyard slopes down, towards the fork of these streets. Two modular classroom units were added to the north side of the building in the late 1970s/early 1980s. One of the two modular classrooms is located at a level that is downhill from the original main school building (the downhill modular). The second modular classroom (the rear modular) was constructed adjacent to the west wall of the original building, roughly on a level at/equal to the main school building. The second floor consists of general classrooms. The first floor contains general classrooms, school offices and a cafeteria. The school library, art room, teachers' workrooms and boiler room are located in the finished areas of the ground floor (basement level). Windows are openable and consist of single paned glass in wooden window frames. The downhill modular, on the north side of the building, was not in use due to microbial growth concerns.

The heating, ventilating and air conditioning (HVAC) system was evaluated by the Richard D. Kimball Company, Inc. (RDK) in December, 1997. The report issued on the findings of this evaluation characterized the condition of the ventilation system as "poor" and recommended replacement (RDK, 1998). A second consulting company, ATC Associates, Inc. (ATC), was retained by the North Andover School Department to conduct an indoor air quality/microbial investigation of the school (ATC, 2001a; ATC, 2001b). The initial investigation was conducted in the music room and in the modular that is located downhill. Based on the results of this investigation, ATC staff made the following recommendations:

1. Replace water-damaged carpeting in the teacher's lounge.
2. Due to presence of microbial contamination in the portable classroom, occupation of the areas should be minimized.
3. Consideration should be made to replace the portable classrooms.
4. Replace water-damaged molding in the music room (ATC, 2001a).

ATC conducted further examination of the remainder of the building on November 3, 2001. As a result of this series of evaluations, ATC staff made the following recommendations:

1. Repair ventilation system exhaust vents.
2. Operate unit ventilators (univents) continuously during occupancy.
3. Clean the interior of univents.
4. Improve the efficiency of filters installed in each univent.

5. Extend the kitchen stovepipe.
6. Cut back shrubbery from univent fresh air intake for music room.
7. Replace carpeting in rooms 4A, 3B, 2A and the nurse's office, with non-porous flooring.
8. Clean the carpet in room 1B.
9. Seal pipe penetrations in fallout shelter to prevent odor migration.
10. Discontinue the use of deodorizers.
11. Replace solvent-based markers with water-based products (ATC, 2001b).

Methods

Air tests for carbon dioxide, carbon monoxide, temperature and relative humidity were taken with the TSI, Q-Trak, IAQ Monitor, Model 8551.

Results

This school has a student population of approximately 190 and a staff of approximately 40. Tests were taken under normal operating conditions at the school and results appear in Tables 1-4.

Discussion

Ventilation

It can be seen from the tables that carbon dioxide levels were above 800 parts per million of air (ppm) in twelve of the twenty-two areas sampled, indicating inadequate air exchange in these areas. Fresh air is provided to classrooms by unit ventilators (univents). Univents draw air from outdoors through a fresh air intake located on the exterior walls of the building and return air through an air intake located at the base of each unit (see Figure 1). Fresh and return air are mixed, filtered, heated and then provided to classrooms through a fresh air diffuser located in the top of the unit. Exhaust ventilation is provided by roof top exhaust motors connected to wall-mounted, louvered grilles by ductwork. Exhaust vents are located within coat closets. The exhaust vents were obstructed with coats and boxes. These vents need to remain unobstructed in order to function as designed. The system was found operating in most areas of the building.

The rear portable classroom has a ventilation system that is separate from the rest of the school. This classroom has ceiling-mounted fresh air diffusers and an exhaust vent, both of which are connected to an air handling unit (AHU) installed on the exterior wall of the modular (see Picture 1). Exhaust air exits through a passive louvered vent by air pressure created by AHU fans as this equipment operates. When the AHU is deactivated, the louvered vent closes. The orientation of the AHU can produce conditions that allow for uncontrolled entrainment of cold air during winter through the passive exhaust vent. The passive exhaust vents face west. Prevailing winter winds are generally northwest (NW). As NW winds blow across the face of the AHU, this airflow can lift the edge of the passive vents and force air in an uncontrolled manner into the return air chamber. In the winter, this condition can introduce cold air that may result in the AHU coils freezing. During warm, humid weather, uncontrolled air introduction can increase condensation inside the AHU cabinet. A thermostat controls the modular AHU with three fan settings: on, off and automatic. The automatic setting on the thermostat activates the AHU system at a preset temperature. Once a preset temperature is reached in the area of the thermostat, the AHU system is deactivated. On the day of the assessment the thermostat was set to the automatic setting, which had turned off the modular classroom's ventilation system. Modular classrooms are designed to be energy efficient. Therefore little outside air penetration occurs, except when windows are open. The sole supply of fresh air within this room is the ventilation system. Once switched from the automatic setting to the on setting, carbon dioxide levels dropped as fresh air circulated through this room.

In order to have proper ventilation with a mechanical supply and exhaust system, the systems must be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air. The date of the last servicing and balancing of these systems was not available at the time of the assessment. It is recommended that HVAC systems be rebalanced every five years (SMACNA, 1994).

The Massachusetts Building Code requires a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or have openable windows in each room (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week, based on a time-weighted average (OSHA, 1997).

The Department of Public Health uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information concerning carbon dioxide, please consult Appendix 1 of this assessment.

Temperature readings were measured in a range of 69° F to 76° F, which was very close to the BEHA recommended comfort range. The BEHA recommends that indoor air temperatures be maintained in a range of 70° F to 78° F in order to provide for the comfort of building occupants. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply.

Relative humidity in the building was below the BEHA recommended comfort range of 40 to 60 percent in all areas sampled the day of the assessment. Relative humidity measurements ranged from 19 to 28 percent. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a very common problem during the heating season in the northeast part of the United States.

Microbial/Moisture Concerns

A factor that may be contributing to moisture noted in the basement is water accumulation along the base of the main building. Water stains were noted on the floor near the rear exterior wall of the library on the ground floor. Efflorescence (i.e. mineral deposits) was observed on the brickwork on the interior walls in the guidance room (see Picture 2). Efflorescence is a characteristic sign of water intrusion. As moisture penetrates and works its way through mortar around brick, it leaves behind these characteristic mineral deposits. Efflorescence on carpeting edges and brickwork indicate that these materials have been chronically wetted.

Along the building outside the guidance room, plants were noted growing in the junction between the exterior wall and the tarmac (see Picture 3). Water can gather in the wall/tarmac seam where these plants were observed. Plants collect water that penetrates into the tarmac/exterior wall junction. Freezing and thawing of gathered water can result in damage to the exterior wall, which can result in water penetration into the building.

In each of these cases, chronic wetting can result in mold colonization of carpets. The American Conference of Governmental Industrial Hygienists (ACGIH) recommends that porous materials be dried with fans and heating within 24 hours of becoming wet (ACGIH, 1989). If porous materials such as wallboard and carpeting are not dried within this time frame, mold growth may occur. Water-damaged carpeting cannot be adequately cleaned to remove mold growth.

A drainage system exists in the front of the building that would remove accumulated rainwater. The drain for this area consists of a culvert that is currently blocked with a plastic bag. School staff reported that this culvert was blocked to prevent sewer odors from penetrating through ground floor windows. Prior to attempts to block the culvert, reports of sewer odors were chronically reported in the ground floor. This blockade may result in water accumulation within this drainage system, which may, in turn, produce water penetration through the ground floor foundation walls.

Shrubbery in direct contact with the exterior wall brick was noted along the front of the building (see Pictures 4 and front cover). Shrubbery can serve as a possible source of water impingement on the exterior curtain wall due to plants growing directly against the building. Plants retain water and in some cases can work their way into mortar and brickwork causing cracks and fissures, which may subsequently lead to water penetration and possible mold growth. Each of these conditions allows for the accumulation of water along the base of the building, which can lead to moisture penetration into the basement.

Several areas had a number of water-damaged ceiling tiles as well as wall plaster. Window frames appear to be original and also exhibit signs of water damage. Water damage to the interior can occur through leaks in the window frames. Porous building materials (e.g., ceiling tiles and wall plaster) can serve as growth media for mold, especially if wetted repeatedly. These materials should be replaced after a water leak is discovered.

The first floor boy's restroom has urinals installed on gypsum wallboard (GW) (see Picture 5). The original units installed in this restroom were installed in the floor. When the original urinals were removed, a depression was left in the floor underneath the GW. These depressions can accumulate water, which may then wet GW. Chronically moistened GW can grow mold.

Modular Classrooms

Both modular sections were examined. Guidance concerning preventing mold growth in modular classrooms was recently released in March, 2002 by the Modular Building Institute (Stewart, 2002). According to this guidance, the following improvements can be made to avoid microbial growth within these structures:

1. Use of sloped roof with properly installed gutter and downspout system to drain rainwater.
2. Siting the structure on a well drained surface.
3. Surface run-off should be directed away from the structure.
4. The crawlspace under the structure should be well ventilated.
5. Check all caulking and/or flashing around windows and service posts, especially after moving a structure.
6. Maintain ventilation according to American Society for Heating, Refrigerating and Air-conditioning Engineers (Stewart, B., 2002).

Using these guidelines as evaluation points, the following is an analysis of each, for each modular unit.

The Rear Modular Unit

The exterior walls of the rear modular unit appeared to be intact. Drainage for this unit appears to be adequate. No downspout or gutter system exists for this unit, which allows for water on the roof to splash on the tarmac to wet the exterior wall of the modular in several areas (see Picture 6). There are minimal means for ventilating the crawlspace under this structure. Under these circumstances, continued exposure to water to the exterior walls may result in damage to the modular building in the future.

The Modular Unit Located Downhill

The exterior walls of the modular unit located downhill were in disrepair, with a number of open seams, breaches and other damage. While this unit is located on a slope, the drainage for the tarmac playground behind the school appears to direct groundwater into the rear wall of this structure (see Pictures 7 and 7A). The configuration of this modular unit is the form of the letter "T", with its base joined to the original building. This configuration creates conditions for snow from the sloped roof to accumulate in contact with the modular unit's exterior wall (see Picture 8). As snow melts, it wets the exterior wall. No downspout or gutter system exists, allowing water on the roof to splash on the tarmac to wet the exterior wall of the modular in several areas. No means exists for ventilating the crawlspace under this structure. Several of the interior walls of the modular unit located downhill were opened as part of previous assessments. These walls where made of gypsum wallboard covered with vinyl wallpaper. Vinyl wallpaper is a water impermeable barrier, which prevents water evaporation and can lead to microbial growth on GW if water penetrates into the structure. In this case, there appears to be ample opportunity for water to penetrate into the interior of this structure.

Other Concerns

Missing ceiling tiles, as well as spaces and holes in the interior walls and floors were observed. Since wall cavities are unconditioned space and would be expected to have a lower temperature than heated areas, drafts of air moving from the wall interiors into rooms may occur. Particulates can move with airflow from the interior of the wall cavity into the room. Each of these breaches in the floors and walls can be a means for odors and particles to move from one area to another.

Airflow into the univent is controlled by a pendulum type louver that covers both the fresh air intake and return vents. This configuration requires that two separate filters be installed over the fresh air intake and return vents (see Picture 9). While the return vent filter appeared to be replaced regularly, the fresh air intake vent filter was heavily coated with debris, indicating that it had not been changed. According to school maintenance personnel, the existence of these filters was not known, so no estimate could be made as to the date of the last change. Maintenance staff have since made arrangements to have all second filters of univents changed.

Filters installed in univents provide minimal respirable dust filtration. In order to decrease aerosolized particulates, disposable filters with an increased dust spot efficiency can be installed. The dust spot efficiency is the ability of a filter to remove particulates of a certain diameter from air passing through the filter. Filters that have been determined by ASHRAE to meet its standard for a dust spot efficiency of a minimum of 40 percent would be sufficient to reduce airborne particulates (Thornburg, D., 2000; MEHRC, 1997; ASHRAE, 1992). Note that increased filtration can reduce airflow produced by the univent through increased resistance (called pressure drop). Prior to any increase of filtration, univents should be evaluated by a ventilation engineer to ascertain whether they can maintain function with more efficient filters.

Spaces around pipes were noted within all univent cabinet interiors surveyed. Open pipes and spaces around pipes can serve as pathways for dust, dirt, odors and other pollutants to move from the floor/wall cavities into occupied areas during operation of univents.

Areas throughout the building contain computers, photocopiers and fax machines. Volatile organic compounds (VOCs) and ozone can be produced by photocopiers, particularly if the equipment is older and in frequent use. Ozone is a respiratory irritant (Schmidt-Etkin, D., 1992). As discussed previously, without mechanical ventilation, excess heat, odors and pollutants produced by office equipment can build up and lead to indoor air quality complaints.

Conclusions/Recommendations

The recommendations are divided into those that apply to the main building and those that apply to the modular classrooms. In order to improve indoor air quality the following recommendations are made:

Main Building

1. Replace the fresh air filter in each univent. Change filters as per the manufacture's instructions or more frequently if necessary.
2. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. To control for dusts, a HEPA filter equipped vacuum cleaner in conjunction with wet wiping of all surfaces is recommended. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).

3. In order to decrease aerosolized particulates, disposable filters with an increased dust spot efficiency can be installed in univents. Ensure that installed filters are of a proper size and installed in a manner to eliminate particle bypass of the filter. Note that increased filtration can reduce airflow produced by the univents by increased resistance. Prior to any increase of filtration, each unit should be evaluated by a ventilation engineer.
4. Repair damaged window frames to prevent water penetration into the building.
5. Replace water-damaged and missing ceiling tiles.
6. Improve drainage along the exterior wall to direct rainwater away from the base of the building.
7. Cut back or consider removing shrubbery from the exterior wall of the front of the building.
8. Remove all vegetation from the exterior wall/tarmac seam. Reseal tarmac seams and cracks. Seal the exterior wall/tarmac junction with a water impermeable sealant.
9. Examine the feasibility of repairing the culvert in a manner to provide drainage but eliminate sewer odor production.
10. Remove GW six inches above floor depressions shown in Picture 5 to prevent mold growth. Do not replace GW.
11. Examine the feasibility of providing exhaust ventilation for photocopiers. If not feasible, position photocopier near exhaust vent to draw pollutants away from occupied area.

Rear Modular Unit

1. Install downspouts to drain water from the roof and deliver water to the tarmac in a manner to prevent splashing or moistening of the exterior wall.
2. Improve ventilation of crawlspace beneath modular unit by installing large passive air vents. If this is done, ensure that the underflooring is sufficiently insulated.
3. Examine the feasibility of installing a metal awning over the outside of the exhaust vent to limit lifting of the flap by northwesterly winds.
4. Set the thermostat for this classroom to the fan "on" position to operate the ventilation system continuously during the school day.

Modular Unit Located Downhill

1. A decision should be made concerning the viability of this structure as occupied space. The water damage and mold growth in floors and walls would militate against repairing these classrooms. Therefore, replacement as recommended by ATC may be the most cost effective measure.
2. BEHA would not recommend reoccupancy of these classrooms unless extensive renovation to remove water-damaged materials and restoring the building envelope integrity is done.
3. Seal the entrance to this area with a sheet of polyethylene plastic and duct tape to prevent odor migration into the stage stairwell.

References

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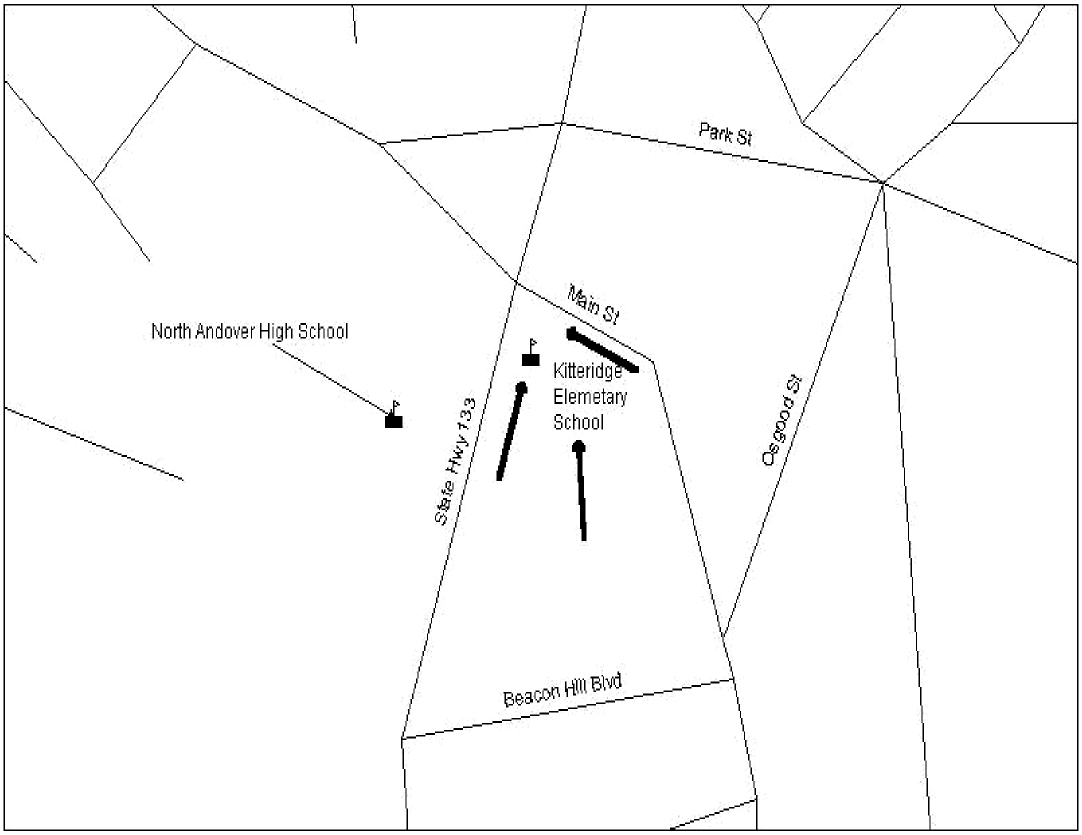
Map 1



Location of Kitteridge Elementary School

(Arrows Denote Direction of downward Slope of Ground around the Building)

Picture 1

The Rear Modular AHU

Picture 2

Efflorescence (i.e. Mineral Deposits) Observed on Brickwork of the Interior Walls in the Guidance Room

Picture 3

Plants Noted Growing in the Junction between the Exterior Wall and the Tarmac

Picture 4

Shrubbery in Contact with Exterior Wall of School

Picture 5

Depressions in Floor of Boy's Restroom Underneath GW;
Note Discoloration of GW Above Floor Depression

Picture 6

Wetted Exterior Wall of the Rear Modular
Caused by Water Splashing on the Tarmac Due to a Lack of Gutter/Downspout System

Picture 7

Drainage Pattern for the Tarmac Playground Behind the School Appears to Direct Groundwater into the Rear Wall of the Downhill Modular

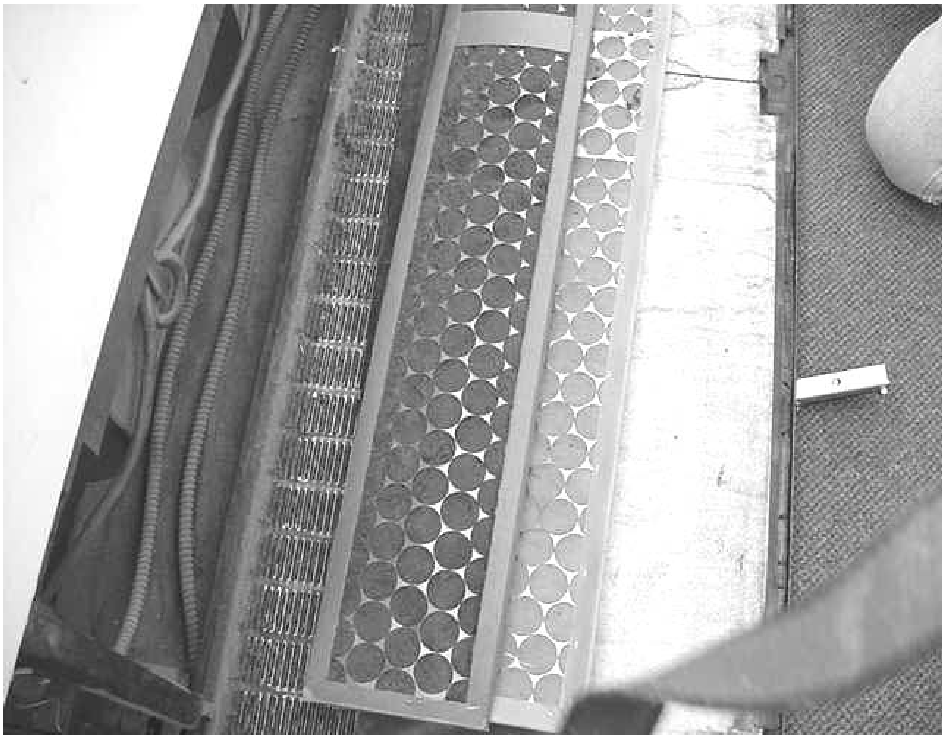
Picture 7A

Close-Up of Drainage Pattern for the Tarmac Playground Behind the School

Picture 8

Snow Accumulation against Downhill Modular Exterior Wall

Picture 9



Two Filters within Each Univent, Filter on Left is Recently Replaced

TABLE 1

Indoor Air Test Results – Kitteridge Elementary School, North Andover, MA – January 22, 2002

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
Outside (Background)	340	40	29					Weather conditions: sunny, clear
Principal's Office	981	73	28	3	Yes	No	No	Personal fan, restroom-no exhaust, window-mounted air-conditioner, 7 plants-drip pans, door and windows open
Girl's Restroom (2nd floor)					Yes	No	Yes	Exhaust weak/off, window open, wall crack
Room 5B	1081	74	25	18	Yes	Yes	Yes (3-Closet)	Univent-heat only, exhaust vents-weak/off, personal fan, carpet, chalk dust, 7 computers, accumulated items
Room 5A	950	74	23	20	Yes	Yes	Yes (3-Closet)	Univent-heat only, exhaust-off, carpet, dry erase board, door open
Nurse's Office	548	72	19	4	Yes	No	No	Window and door open, carpet, sink, window-mounted air-conditioner, exhaust fan in adjacent restroom-sealed with plywood

*** ppm = parts per million parts of air**
CT = ceiling tiles

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred
	600 - 800 ppm = acceptable
	> 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

TABLE 2

Indoor Air Test Results – Kitteridge Elementary School, North Andover, MA – January 22, 2002

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation Intake	Ventilation Exhaust	Remarks
Secretary's Office	586	71	22	1	Yes	No	No	Window and door open, photocopier, carpet, adjacent restroom-window, 1 water-damaged CT, sink, cleaning products
Girl's Restroom (1st floor)					Yes	No	Yes	Window and door open, exhaust-weak/off, water damage-around window/pipes, utility holes
Room 2A	1567	72	28	20	Yes	Yes	Yes (3-Closet)	Univent off, exhaust vents obstructed, chalk dust, 6 water damaged CT, dry erase board, carpet, personal fan, accumulated items, door open
Room 2B	1265	74	26	20	Yes	Yes	Yes (3-Closet)	Univent off, exhaust vents obstructed/off, utility holes, chalk dust, dry erase board, carpet, missing CT, spray cleaner/ artificial snow/ spray polyurethane/ hairspray/ rubber cement, plaster of paris in closet
Boy's Restroom (1st floor)					Yes		Yes	Window open, window mounted exhaust fan, exhaust vents-sealed, utility holes

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Relative Humidity -	40 - 60%

TABLE 3

Indoor Air Test Results – Kitteridge Elementary School, North Andover, MA – January 22, 2002

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
Kitchen	573	69	21	2	Yes	No	No	Window open-screens, gas stove/ovens-exhaust hood-"never used" (CO=0), "furry" pipe insulation
Book Room		70	24	0				Holes/cracks @ ceiling/ceiling-wall junction, broken window, door open, dust odor
Library	565	69	23	1	Yes	Yes	Yes	Univent off, exhaust blocked, ~8 computers, utility holes, missing CT
Teacher's Room	1269	71	28	9	Yes	No	No	Water cooler, refrigerator
Buttercup Room	537	71	22	0	No	No	No	Utility holes, passive vent in wall-sealed, door open, roof/ceiling nails, exposed fiberglass
Basement Office	571	70	22	0	Yes	No	No	Door open
Guidance Office	952	71	24	1	Yes	No	No	3 occupants gone <5 mins., chalk dust, carpet, 2 water damaged CT, utility holes, deteriorated mortar
Room 4B	1101	74	27	22	Yes	Yes	Yes	Window and door open, univent off, dry erase board

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Temperature -	70 - 78 °F
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TABLE 4

Indoor Air Test Results – Kitteridge Elementary School, North Andover, MA – January 22, 2002

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation Intake	Ventilation Exhaust	Remarks
Room 4A	1488	74	27	19	Yes	Yes	Yes	Univent off, accumulated items
2nd Floor Hallway	792	76	23	4	No	No	No	Door open
Room 1A	1010	73	27	16	Yes	Yes	Yes	Pillow obstructing univent, coats/boxes obstructing exhaust vents, door open
Room 1B (portable)	981	76	25	19	Yes	Yes	Yes	Supply and exhaust off, door open
Room 3A	674	72	21	16	Yes	Yes	Yes	Supply and exhaust off, window open, 2 water-damaged CT
Room 3B	668	73	22	15	Yes	Yes	Yes	Supply and exhaust off, spray cleaner
Cafeteria	847	72	23	80+	Yes	Yes	Yes	Supply and exhaust off
Art Room	620	69	24	5	Yes	Yes	Yes	Supply off, door open

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